The Queen's Jubilee Prize Essay of the Royal Botanic Society of London.

IN your issue of October 18 appears (p. 594) a review of the essay for which I was awarded the medal of the Royal Botanic Society, in which the writer makes a great point of my omitting all reference to drugs. He does not state, for the information of your readers, that the prize was offered for the best (not necessarily complete) essay on the "Vegetable Substances introduced into Britain for use in the Arts, Manufactures, Food, and Domestic Economy during the Reign of Her Majesty Queen Victoria." It is not necessary that one should be either "a member of the medical profession" or have "a wholesome dread of drugs" to know that drugs used as medicines could not with any fitness be introduced into this essay; indeed, inquiry from the Secretary elicited the fact that they had been purposely excluded.

Had your reviewer read the essay with any care, he would have observed that I quote Dr. Forbes Watson to the effect that China grass and rhea fibre are products of the *same plant*, but prepared in different ways; while an unprejudiced reviewer would have mentioned that the quotation having reference to *Phormium tenax* is preceded in the essay by the words, "In one of the authorities consulted it is stated that New Zealand flax . . . was introduced into England about 1840; but the author has found a reference to an unsatisfactory attempt to weave it at Knaresborough at a much earlier period than this, and that it had been experimented upon in the Portsmouth Dockyard about 1819, the ropes made from it being satisfactory."

It was evident that the judges considered that "gun-cotton and its derivatives" *are* "direct products of the vegetable kingdom," or they would not have printed this chapter of the essay.

The limited time allowed for the preparation of the essay (about four months), and the inability of the author to avail himself of any collection of economic botany and of many of the most recent books on the subject, naturally led to many deficiencies in the list of substances mentioned, and of this no one was more conscious than the author himself; and all he claims for his essay is that, in the opinion of the judges (one of whom was Prof. Bentley), it was the best of the half-dozen sent in in competition.

JOHN W. ELLIS.

3 Brougham Terrace, Liverpool, October 23.

I HAVE but few remarks to make in answer to Mr. Ellis's letter. First, I cannot follow his reasoning that completeness should not in some measure count as a test of quality, nor can I see anything in the preamble of the offer of the prize to exclude drugs. Mr. Ellis is justified, however, in having done so by receiving direct information from the Secretary to that effect.

On the subject of China grass and rhea, the author, in his essay, distinguishes them under separate heads, describing the first rightly as the produce of *Bœhmeria nivea*, and the second as "the produce of the East Indian *Bœhmeria* (*Urtica*) *tenacissima*, a congener of the species producing China grass." It is after this authoritative statement that he refers to Dr. Forbes Watson's opinion.

Regarding New Zealand flax (*Phormium tenax*), Mr. Ellis, in his essay, follows up the quotation given in his letter by the following paragraph: "Not having been introduced during the period to which this essay refers, any further mention of this interesting fibre—for which it has frequently been attempted to find a place in the British market—is unnecessary;" thus justifying my remarks on this head.

I leave it to anyone who has read Mr. Ellis's chapter on "Gun-cotton and its Derivatives," to say whether they are direct products of the vegetable kingdom.

The latter part of Mr. Ellis's letter, I think, supports the truth of my review generally.

THE REVIEWER.

October 27.

MODERN VIEWS OF ELECTRICITY.[1]

PART IV.—RADIATION.

XII.

WE must now mention one or two phenomena which depend entirely upon a modification of ether by the neighbourhood of matter, and which we have reason to believe would not occur in free ether at all. These are the optical phenomena of Faraday and Kerr, and the electric phenomenon of Hall.

Faraday discovered, long before there was any other connection known between electricity and light, that the plane in which light-vibrations occur could be rotated by transmitting light through certain magnetized substances along the lines of magnetic force. To make this effect easily manifest, one uses plane-polarized light and transmits it through a fair length of magnetized substance, analyzing it after emergence, and showing that, though it remains plane-polarized, the plane has been rotated, possibly through a right angle or more.

Now, in a general way it is easy to imagine that, inasmuch as something of the nature of a rotation is going on in a magnetic field round the lines of force, vibrations travelling into such a field along these lines should be twisted round, corkscrew fashion, and emerge vibrating in a different plane. But when one tries to follow out this process into detail, one finds it not quite so simple a matter. It has no business to be a very simple and obvious consequence of the existence of a magnetic rotation round the rays of light, else would it occur in free space, and in the same direction in all media. But the facts are that in free space—that is, in free ether—it does not occur at all, and the direction of rotation is not the same for all media: substances can, in fact, be divided into two groups, according to the way in which given magnetization shall rotate the plane of polarized light passing through them.

Similarly with the electrostatic optical effect discovered by Dr. Kerr, who showed that plane-polarized light transmitted across the lines of force in an electrostatic field could, in certain media, come out elliptically polarized. Now, inasmuch as an electric field is a region of strain, and strain in transparent bodies is well known to make them slightly doubly refracting and able to turn plane-polarized into elliptically-polarized light, it is very easy to imagine such a result in an electric field to be natural and probable. But the explanation is not so simple as that, else it ought to be a large effect, occurring in all sorts of media in the same direction, and likewise in free space. But the facts are that it does not occur at all in free space, and it occurs in different senses in different substances; so that again they can be grouped into two classes according to the sign of the Kerr effect.

Thus, then, the rotatory effect of a magnetic field upon light, discovered by Faraday, and the doubly refracting effect of an electrostatic field upon light, discovered by Kerr, agree in this: that they are both small or residual effects, depending on the existence of a dense medium, and both varying in sign according to the nature of the medium.

The only substance in which the Faraday effect is large is iron, including with iron the other highly magnetic substances. The discovery of the effect in these bodies was likewise made by Kerr. The difficulty of dealing with them is that they are very opaque, and hence that the merest film of them can be used. The film can be used either by way of transmission or by way of reflection, it matters not which, but reflection is perhaps the more convenient. Light reflected from the pole of a magnet has indeed barely penetrated at all into the substance of the iron before being sent back; still, it has penetrated deep enough to be distinctly rotated by the tremendous magnetic whirl which it finds there. All these highly magnetic substances are metallic conductors, and are therefore very opaque.

Whether there is any real connection between high magnetic susceptibility and conductivity is more than I can say. But it is quite natural, and indeed necessary, that the greatest portion of light should be reflected on entering a highly magnetic medium, because in such a medium the ethereal density, μ, is so great, and hence the velocity of wave transmission must undergo a sudden and immense decrease—a circumstance always causing a great amount of reflection, just as when sound tries to pass from any one medium to a much denser one.

---

[1] Continued from vol. xxxviii. p 592.

But the opacity of iron and other magnetic substances may be explained by the mere fact of their conducting power, just like other metals, and no noteworthy effect of their large value of μ need be detectable.

If a non-conducting highly magnetic substance could be found, it would probably reflect a great deal of light at its surface, though it would not dissipate that which entered it. Such a substance would be most interesting to submit to experiment, but perhaps its existence presupposes a combination of impossible properties.

As to the phenomenon detected by Hall, it appears intimately associated with that of Faraday, and it will be most simple to omit all reference to it for the present.

A general idea of what is happening in the Faraday and Kerr phenomena can be given thus. A simple vibration, like a pendulum-swing, or any other oscillation in one plane, can be resolved into two others in an infinite variety of ways; just as one force can be resolved into any number of pairs of equivalent forces. The two most useful modes of analyzing a simple vibration into a pair of constituents are these: (1) two equal components, likewise plane vibrations, each inclined at 45° to the original one, as when P Q is resolved into A B and C D (Fig. 49); and (2) two equal circular or rotatory oscillations in opposite directions, as when P Q is resolved into P M Q and P N Q (Fig. 50). The first method of resolution is useful in explaining Kerr's effect, the second in explaining Faraday's.

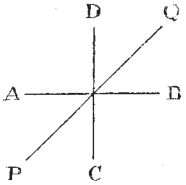

FIG. 49.

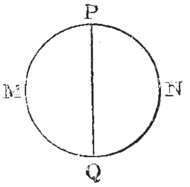

FIG. 50.

Of the two component vibrations, A B and C D, into which P Q can be supposed analyzed, let some cause, no matter what, make one gain upon the other, so that in travelling along a line perpendicular to the paper one goes a little the quicker: the effect at once is to change the character of the vibration into which they will recompound. After the gain, they no longer reproduce the original simple vibration P Q: they give rise to elliptic, or it may be to circular, vibrations; this last, if the retardation is equal to a quarter period.

These are matters fully treated in any elementary treatise on polarized light, and they are quite easily illustrated by means of a simple pendulum. One may assume them known.

Similarly with the second system of analyzing the vibration into two opposing circular ones. If the components travel through any interposed medium at the same rate, they will, on emergence, reproduce the original vibration in its original position; but if one travels quicker than the other they recombine into a vibration of the same character as at first, but turned through a certain angle. Thus anything which retards one of the *rectangular* components behind the other changes the character of the vibration from plane into elliptical; while anything which retards one of the *circular* components behind the other leaves the character of the vibration unaltered, but rotates it through a certain angle.

So far one has said nothing but the simplest mechanics. The next point to consider is what determines the rate at which light travels through any substance? This we have discussed at length, and shown to be $\frac{1}{\sqrt{(K\mu)}}$. Anything which increases either the electric or the magnetic permeability of the medium decreases the velocity of light. Now, when a medium is already subject to a violent strain in any one direction it is possibly less susceptible to further strain in that direction and responds less readily. Not necessarily so at all: such an effect would only be produced when the strain was excessive, when the medium was beginning to be overdone, and when its properties began thereby to be slightly modified. There are reasons for believing the specific inductive capacity of most media to be very constant; of some media, perhaps, precisely constant; but if there were any limit beyond which the strain could not pass it is probable that on nearing that limit the specific inductive capacity would be altered—possibly increased, possibly diminished—one could hardly say which. Quincke has investigated this matter, and has shown that the value of K is affected by great electric strain.

Suppose now that a dielectric is subject to a violent electrical stress, so that its properties along the lines of force become slightly different from its properties at right angles to those lines. The value of K will not be quite the same along the lines of strain as across them, and accordingly the rectangular component of a vibration resolved along the lines of force will travel rather quicker or rather slower than the component at right angles, because the velocity of transmission depends upon K as already explained: such a medium at once acquires the necessary doubly-refractive character, and will show Kerr's effect.

Similarly with magnetization. It is well known that for many media μ is not constant. Take iron, for instance. For very small magnetizing forces the susceptibility is moderate, and increases as they increase; at a certain magnetization it reaches a maximum, and then steadily decreases. But not only is it thus very inconstant, its ascending and descending values are not the same. To forces tending to magnetize it more, the susceptibility has one value; to forces tending to demagnetize it, it has another and in general smaller value. This property has been specially studied by Ewing, and has been called by him "hysterĕsis." Slightly susceptible substances cannot be magnetized to anything like the same extent, and hence the property in them has been less noticed, perhaps not noticed at all. Nevertheless it must exist in every substance which exhibits a trace of permanent magnetism, and every substance I have tried appears to show some such trace (see NATURE, vol. xxxiii. p. 484).

An already strongly magnetized medium will be rather differently susceptible to additional magnetizing forces in the same direction than to those in a contrary direction. Nothing more is wanted to explain Faraday's effect. The vibration being resolved into two opposite circular components, one of them must agree in direction with the magnetism already in the medium and try to magnetize it for the instant infinitesimally more; the other component will for the instant infinitesimally tend to demagnetize it. The value of μ offering itself to the two components will be different, hence they will go at different rates, and the plane of vibration will be rotated.

The direction of rotation will depend on whether the value of μ is greater for small relaxations or for small intensifications of magnetizing force; and diamagnetic substances may be expected to be opposite in this respect to paramagnetic ones. Any substance for which μ is absolutely constant, whatever the strength of magnetic polarization to which it is submitted, can hardly be expected to exhibit any hysterĕsis; the ascending and descending curves of magnetization will coincide, being both straight lines, and such a substance will show no Faraday effect. Similarly, any substance for which K is absolutely constant, whatever the electric polarization to which it is submitted, can show no Kerr's effect. Free space appears to be of this nature; and gases approach it very nearly, but not quite.

In iron, μ is greater for an increasing than for a decreasing force, as is shown by the loops in Ewing's curves; hence the circular component agreeing in direction with the magnetizing current will travel slower than the other component, and hence the rotation in iron will be against the direction of the magnetizing current. The same appears to hold in most paramagnetic substances, and the opposite in most diamagnetic, but the mere fact of paramagnetism or diamagnetism is not sufficient to tell us the sign of the effect in any given substance. We must know the mode in which its magnetic permeability is affected by waxing and by waning magnetization respectively.

Possible Electrical Method of detecting the Faraday Effect.

Thus far we have considered the rotation of electric displacement by a magnetic field as being examined optically, the displacements being those concerned in light, and the rotation being detected by a polarizing analyzer suitable for determining the direction in which the vibrations occur before and after the passage of light through a magnetized substance. This is the only way in which the effect has at present been observed in transparent bodies. But one ought not to be limited to an optical method of detection.

Electrical displacements are easily produced in any insulator, and if it be immersed in a strong magnetic field so that the electric and magnetic lines of force are at right angles to each other, every electric disturbance ought to experience a small rotation. A steady strain will not be affected; it is the variable state only which will experience an effect, but every fresh electric displacement should experience a slight rotatory tendency just like the displacements which occur in light.

Now to rotate a displacement A B into the position A C requires the combination with it of a perpendicular displacement B C (Fig. 51). Hence the effect of the magnetic field upon an electric displacement, A B, may be said to be the generation of a small perpendicular E.M.F., B C, which, compounded with the original one, has the resultant effect A C. It will be only a temporary effect, lasting while the displacement is being produced, and ceasing directly a steady state of strain is set up.

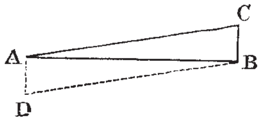

FIG. 51.

An inverse E.M.F., A D, will be excited by the same magnetic field directly the displacement is reversed.

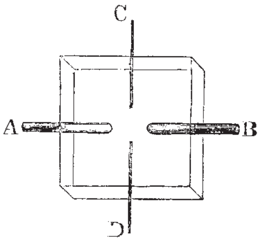

FIG. 52.

And so, if a continual electric oscillation is kept up between A and B in a magnetic field, an accompanying very minute transverse oscillation may be expected, and may be looked for electrically.

Some such arrangement as that here shown (Fig. 52) may be employed. A square of heavy glass, perforated with four holes towards the centre, supplied with electrodes; one pair of electrodes, A, B, to be connected with the poles of some alternating machine, and the other pair, C, D, connected to a telephone or other detector of minute oscillatory disturbance. So soon as a strong steady magnetic field is applied, by placing the glass slab between the poles of a strong magnet, the telephone ought to be slightly affected by the transverse oscillations. This effect has not yet been experimentally observed, but it seems to me a certain consequence of the Faraday rotation of the plane of polarization of light.

Hall Effect.

Although the existence of this transverse E.M.F., excited by a magnetic field in substances undergoing varying electric displacement, has at present only been detected optically in transparent bodies, *i.e.* in insulators, yet in conductors the corresponding effect with a steady current has been distinctly observed electrically. By many persons it had been looked for (by the writer and Prof. Carey Foster, among others, though unfortunately they were not sufficiently prepared for its extreme smallness); by Mr. Hall, at Baltimore, was it first successfully observed.

In conductors it is natural to use a conduction-current instead of a displacement-current. A steady current can be maintained in a square or cross of gold-leaf or other thin sheet of metal between the electrodes A, B, and a minute transverse E.M.F. can be detected, causing a very weak steady current through a galvanometer connected to the terminals C, D, so soon as a strong magnetic field is applied perpendicularly to the plate. Fig. 53 will sufficiently indicate the arrangement. The poles of the magnet are one above and one below the paper.

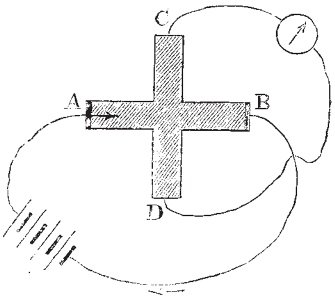

FIG. 53.—The direction of the transverse E.M.F. excited by the earth's vertical magnetic field in this conductor, conveying a current as shown, is C D if it represents gold, D C if it represents iron.

In iron it is easy to see which way the transverse E.M.F. ought to be found. It has been shown that a displacement will be rotated in iron against the magnetizing current; hence, to rotate the displacement A B to A C (Fig. 51), requires in iron a clockwise magnetizing current. Such a current, or, what is the same thing, a south pole below the paper, a north pole above, excites, in the cross of Fig. 53, E.M.F. in the direction D C, and this by Ampère's rule is just the direction in which the conductor itself is urged by the magnetic forces acting on the current-conveying substance. Most diamagnetic substances should exhibit a transverse E.M.F. in the opposite sense. This transverse E.M.F. excited in conductors conveying a current in a magnetic field is the effect known by the name of Hall. It is, as Prof. Rowland and others have pointed out, intimately connected with the Faraday rotation of light.

Unfortunately a pure and simple Hall effect is a difficult thing to observe. Magnetism affects the conductivity of metals in a rather complicated manner, and strain affects their thermo-electric properties. Now, a metal conveying a current in a magnetic field is certainly more or less strained by mechanical forces, and hence heat will be developed unequally in different parts, by a sort of Peltier effect; and the result of this will be to modify the resistance in patches and so to produce a disturbance of the flow which may easily result partly in a transverse E.M.F. This has been pointed out by Mr. Shelford Bidwell.

The more direct effect of magnetism on conductivity may be negligibly small in many metals, but in bismuth it is certainly large. Both of these spurious effects seem to be large in bismuth, and probably quite mask any true Hall effect there may be in that metal. In all cases the existence of these spurious effects makes it difficult to be sure of the magnitude and sign of the real rotational effect.

But, it may be asked, what right have we to distinguish between a real and a spurious Hall effect? If a transverse E.M.F. can be predicted by reason of known strains and thermo-electric properties, as well as by known rotation of light effects, why should the two things be considered different? Why should they not be different modes of regarding one and the same phenomenon?

In other words, may not the Faraday rotation of light vibration be due to infinitesimal temporary strains and heatings in the medium caused by the fact that minute electric displacements are occurring in a violent magnetic field? This is a question capable of being answered by a quantitative determination of the amounts and direction of the effects to be expected, and a comparison with those actually observed. I do not know of data at present obtained sufficient to enable us to answer it. If the answer should turn out to be in the affirmative, the phenomenon of hysteresis will be at once linked, by an underground path, with those of thermo-electricity and strain.[1]

OLIVER J. LODGE.

(*To be continued.*)

IRREGULAR STAR CLUSTERS.

It is not always easy to distinguish between a casual "sprinkle" of stars and a genuine cluster. The movement-test, by which so many physical have been discriminated from optical double stars, is here inapplicable. The Pleiades are the only considerable group possessing an ascertained common proper motion. All other clusters, debarred as yet from the appeal to this demonstrative argument of their physical nature, have to depend solely upon evidence from probability, with its indefinite variations of conclusiveness according to the circumstances of each particular case. It is, however, in general, amply sufficient. Among five hundred clusters registered as such, there are few indeed as to which there can be any doubt of their forming separate systems; although many real aggregations may exist unrecognized, owing to their loosely scattered character.

Two inferences may be safely derived from the results of recent inquiries into the constitution of the Pleiades. First, that interstitial movements in clusters are likely to be so extremely slow that centuries must elapse before they can become conspicuous; next, that stars showing somewhat marked displacements are presumably mere travellers across, and no genuine components of, the cluster they seem to belong to. An example of this kind of temporary association is almost certainly furnished by an apparent member of a scattered group in Ophiuchus ("Gen. Cat." 1440), the position of which was found, by the comparison of photographs taken by M. von Gothard in 1886 with Vogel's measures of eighteen years previously, to have changed to the extent of 45″, or at the rate of $2\frac{1}{2}''$ annually (*Astr. Nach.*, No. 2777). Its motion, if rectilinear, would carry it from end to end of the collection it is projected upon, in 360 years; and its eventual detachment from it may have become palpably inevitable within ten. The star is of the eleventh magnitude, and is by far the swiftest-moving yet known of so small a size.

Several of the stellar gems surrounding κ Crucis are suspected of considerable mobility. Sir John Herschel, during his visit to the Cape, determined the relative places of 110, all included in an area of about $\frac{1}{48}$ of a square degree ("Cape Observations," p. 17); and the process was, by Mr. H. C. Russell, of Sydney, in 1872, repeated and extended to 130 components (*Monthly Notices*, vol. xxxiii. p. 66). The result was to bring out discrepancies which, if really due to movements of the grouped stars, would be of extreme interest. Herschel's measurements, however, were necessarily too hasty to be minutely reliable; so that changes depending upon their authority need to be confirmed by continuance before they can be unreservedly accepted. The same qualification applies to M. Cruls's discovery of orbital revolution in three double stars within the precincts of the cluster (*Comptes rendus*, t. lxxxix. p. 435).

The stars about κ Crucis are famous for the loveliness of their varied hues. Blue and green, red and sulphur-coloured orbs shine together in a matchless sidereal picture, setting at the same time a problem in sidereal chromatics by no means easy to solve. There is no evidence of change of tint among them since Herschel's time, but there is some, tolerably conclusive, as to change of brightness.

Many irregular clusters seem to be throughout made up of star-streams and reticulations exactly similar to the inflected appendages of globular clusters. A collection (M 24) visible to the naked eye as a dim cloudlet near μ Sagittarii, and regarded by Sir John Herschel as intimately connected with, if not an actual part of, the Milky Way, was named by Father Secchi "Delle Caustiche," from the peculiar arrangement of its stars in rays, arches, caustic curves, and intertwined spirals. Closely adjacent to it, he noted a group of eleventh magnitude stars forming three spokes, as it were, and the nave of a wheel, the axis of which was occupied by a much brighter close pair (*Atti dell' Accad. Pont.*, t. vii. p. 72).

The same kind of radiated structure is apparent in a stellar swarm near the right foot of Castor (M 35), which, with Lassell's 24-inch mirror, showed as so "marvellously striking an object that no one could see it for the first time without an exclamation." A field 19′ in diameter "is perfectly full of brilliant stars, unusually equal in magnitude and distribution over the whole area. Nothing but a sight of the object itself can convey an adequate idea of its exquisite beauty" (*Monthly Notices*, vol. xiv. p. 76). Admiral Smyth described it as "a gorgeous field of stars from the ninth to the sixteenth magnitudes, but with the centre of the mass less rich than the rest. From the small stars being inclined to form curves of three or four, and often with a large one at the root of the curve, it somewhat reminds one of the bursting of a sky-rocket" ("Cycle of Celestial Objects," p. 168, Chambers). A marvellously perfect photograph of this cluster, taken by the MM. Henry, March 10, 1886, exhibits not less than two thousand stars disposed in a roughly-indicated, eight-rayed figure, the branches often connected by drooping chains, and composed in detail of sinuous lines, or "fantastically crossing arcs" of stars (Secchi, *loc. cit.*).

About one hundred connected stars in Ophiuchus ("G. C." 4346) "run in lines and arches" (J. Herschel, Phil. Trans., vol. cxxiii. p. 460); a collection of eleventh magnitude ones in Sagittarius ("G. C." 4323) are scattered along "zigzag lines." The constituents of a large cluster near the Poop of Argo ("G. C." 1649) struck the elder

---

[1] Perhaps I ought to caution students not to accept my connection of Faraday's or Hall's effect with hysterēsis as in any way authoritative. Until these views have been criticized it will be wise to place no reliance on them.